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ECO-INNOVATION PERFORMANCE IN EU COUNTRIES- INSIGHTS AND GOOD PRACTICES

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ABSTRACT: The development and implementation of eco-innovation are critical components in addressing climate change and advancing sustainable development in Europe. This article examines the integration of eco-innovation within the European Union's policy framework, emphasising its significance in achieving sustainable development goals. Employing the applied research methodology, trends in eco-innovation have been identified, and the analysis has been enriched with case studies of successful practices in selected EU member states. The results indicate substantial differences in the level of eco-innovation implementation, identifying both leading countries and those lagging in adoption. The discussion focuses on the implications of these findings for future research and policy formulation, emphasising the urgent need to integrate eco-innovation into national and regional climate transformation strategies. Such integration is crucial not only for achieving climate neutrality by 2050 but also for maintaining Europe's position as a leader in clean technologies amidst economic and geopolitical challenges. Therefore, eco-innovation is a foundation for building a sustainable and resilient industrial future for Europe. The study underscores the dual role of political support and inclusive collaboration among stakeholders, positioning eco-innovation as a strategic priority in the pursuit of sustainable development and enhancing global resilience.

KEYWORDS: environmental policies, eco-innovation, sustainable development, European Union

Introduction

Nowadays, with the increasing negative climate changes, interest in the environment and the future of the next generations is growing. (Qu et al., 2024; Tagliabue et al., 2021). The business world and society in general are increasingly leading to a search for balanced economic growth accompanied by sustainable practices (López Pérez et al., 2024). Environmental efficiency is an element that interests the entire society. Topics such as global warming and climate change, acidification of forests and freshwater systems, or air quality are environmental issues that are of increasing concern to citizens and decision-makers around the world. (Beltrán-Esteve, & Picazo-Tadeo, 2017). As the world grapples with the pressing challenges of climate change, resource depletion, and environmental degradation, the concept of sustainability has emerged as a critical focus of global discourse (Evans et al., 2017). The concept of the triple bottom line, which comprises environmental, economic, and social dimensions, constitutes a fundamental framework for sustainable development. These three pillars – often referred to as the 3Ps: planet, profit, and people – represent the traditional domains of corporate social responsibility. Sustainable development must be addressed from both microeconomic and macroeconomic perspectives, reflecting the multi-scalar nature of its implementation (Zhu et al., 2023).

In light of this, the transformation of enterprises toward generating positive environmental outcomes – through the integration of technological innovation and societal adaptation – has become a priority within global policy discourse. The implementation of advanced technologies enhances the financial performance of firms by improving production efficiency and reducing operational costs. Simultaneously, it facilitates the emergence of business models that are inherently aligned with sustainability principles. Furthermore, such innovations contribute to environmental mitigation by reducing material consumption and energy usage, thereby extending sustainability benefits to society through mechanisms such as the circular economy (Ferradás-González et al., 2024).

Within this context, the European Union (EU) has positioned itself as a leader in integrating eco-innovation into its policies and practices, aiming to transition towards a more sustainable economy. Addressing the significant environmental and societal challenges of our time requires coordinated efforts across various sectors to facilitate a shift toward a more just and sustainable economy. In recent decades, entities within the public, private, and third sectors have converged around pivotal concepts, including sustainable development, smart growth, green growth, inclusive growth, and the circular economy. These terms, often labelled as buzzwords, embody an eco-modernist outlook that emphasises the pivotal role of technological advancements in addressing the paradox of pursuing indefinite economic expansion within the confines of a planet with limited resources. This viewpoint has spurred the widespread adoption of terms like eco-innovation, innovation for sustainability, environmental innovation, and green innovation, which are increasingly gaining traction among academics and policymakers alike (Colombo et al., 2019). We can observe broad manifestations of innovation, eco-innovation, and circular economy principles (Hojnik et al., 2024). Public policy can be defined as the deliberate contribution of the government to reconcile environment and economic growth and provide guidance and framework for eco-innovation (Naruetharadhol, et al., 2024). Eco-innovation has risen to prominence as a key global policy objective, with many nations actively seeking to implement environmentally friendly technologies that enhance energy efficiency and mitigate environmental degradation (Ullah et al., 2024).

Eco-innovation plays a vital role in reducing pollutant emissions and improving environmental conditions, as it contributes to enhancing environmental performance and can substantially lower emission levels (Wu et al., 2024). The notion of eco-innovation serves as a fundamental element of sustainable development, particularly when emphasising the circular economy. This approach involves the creation of new products and processes intended for reuse, repair, refurbishment, and recycling. Within a circular economy framework, products are perceived as components of a lifecycle, prioritising the extension of their utility. This shift in perspective promotes innovative design by incorporating principles such as longevity, modularity, and recyclability. By effectively closing the loop on resource flows, the circular economy seeks to minimise environmental impacts, conserve natural resources, and reduce the extraction of limited raw materials (Albitar et al., 2024).

Despite the growing scholarly interest in eco-innovation and its environmental impact, a noticeable gap remains in the literature regarding cross-national comparisons of eco-innovation performance and the identification of practical policy approaches in the European context. This article seeks to address this gap by offering a comparative evaluation of EU member states' performance, while also examining the influence of EU policy frameworks. The study aims to clarify how eco-innovation contributes to climate goals and economic sustainability across diverse national contexts.

The primary objective of this article is to thoroughly examine the contribution of eco-innovation to advancing sustainability and addressing climate change among EU member states. The study focuses on identifying and assessing successful eco-innovative approaches adopted by EU member states, while also exploring European Union policies and regulations that support these innovations and their influence on national progress. A central part of the study is to evaluate the eco-innovation performance of countries in the EU and indicate good practices, aiming to provide strategic recommendations for future research and policy development. This study analyses the Eco-Innovation Index, as well as other studies carried out at the European Union level in the field of sustainability and sustainable innovation.

An overview of the literature – Eco-innovation towards sustainable development

Eco-innovation plays a crucial role in advancing sustainable development by integrating environmental considerations into economic growth strategies. The literature highlights various aspects of eco-innovation, particularly its significance in achieving climate goals, promoting circular economy practices, and fostering green investments. The role of eco-innovation in fostering sustainable development is supported by Caglar et al. (2024), who assess the significance of green investments and innovations in promoting ecological sustainability across European nations. Their research highlights that proactive climate action, combined with strategic investments in eco-innovation, can significantly improve environmental outcomes while fostering economic growth. The integration of eco-innovation within the EU's sustainability framework is further explored by Dziura, Vovk, and Raneta (2020), who emphasise its critical role in advancing the circular economy and achieving sustainable development. Their work highlights how eco-innovations are central to the EU's policies, shaping the future of Europe by promoting practices that reduce environmental impact while enhancing economic growth. The concept of eco-innovation, as originally proposed by Fussler and James (1996), emerges as a response to environmental challenges, highlighting the importance of innovation in addressing ecological issues. This concept is essential for facilitating the transition towards sustainability, offering novel solutions that advocate for ecological, green, responsible, and sustainable practices, thereby transcending conventional, fragmented approaches (Cegarra-Navarro et al., 2019). Eco-innovation is rooted in the principles of a circular economy and sustainable production, making it a vital component of sustainable development. It encompasses the introduction of innovative products, processes, marketing strategies, and organisational frameworks that align with the objectives of sustainable development (Derlukiewicz et al., 2023). Capabilities oriented towards sustainability play a crucial role in eco-innovation, underscoring how organisations can adapt to fulfil regulatory requirements, technological advancements, and market expectations in their eco-innovation initiatives. The importance of eco-innovation is particularly pronounced within industrial systems due to its potential to enhance both eco-efficiency and eco-effectiveness. Recent studies have expanded the understanding of innovation systems and explored the interplay between eco-innovation and openness (Shkarupeta & Babkin, 2024). Eco-innovation promotes the advancement of cleaner technologies, sustainable manufacturing techniques, and environmentally friendly products, thereby diminishing the ecological impact of various industries. It can manifest in numerous ways, including the design of easily recyclable items, the utilisation of renewable energy sources, and the development of cutting-edge technologies aimed at reducing greenhouse gas emissions (Guimarães et al., 2024). The concept of eco-innovation plays a fundamental role in sustainable development, particularly when emphasising the circular economy. Scholars typically concentrate on one or more key areas: defining eco-innovation, identifying the drivers and barriers to the adoption of eco-innovative solutions, and assessing the economic rationale for pursuing eco-innovation (Gente & Pattan-

aro, 2019). The growing body of literature presents an increasing number of definitions, as outlined in the study *Eco-innovation: Insights from a Literature Review* by Díaz-García et al. (2015). Eco-innovations help reduce the negative impacts associated with production and consumption processes, regardless of whether their development or implementation is primarily driven by environmental concerns (Carrillo-Hermosilla et al., 2010). There are also other approaches to defining eco-innovation, as noted in Shkarupeta and Babkin (2024). The diversity of eco-innovation definitions is evident through the use of various terms and concepts. Terms such as environmental innovation, eco-innovation, green innovation, sustainable innovation, or sustainability-oriented innovation are frequently employed by researchers. A review of the literature indicates that the first three terms are often used interchangeably. Meanwhile, 'sustainable innovation' aligns with the concept of sustainable development, as defined by the World Commission on Environment and Development (also known as the Brundtland Commission), which views development as fulfilling present needs without jeopardising the ability of future generations to meet their own needs. The role of sustainable innovation as a means of promoting sustainable development is depicted in Figure 1 (Pichlak & Szromek, 2021). Eco-innovation refers to the development of innovative products and processes that reduce environmental impacts (Sarkar, 2013). Eco-innovation aims to facilitate the transition to a resource-efficient circular economy by transforming business models, changing citizen interactions with products and services, and improving value delivery systems (Machiba, 2013). Eco-innovation can be defined as the 'development, implementation, or application of a product, production method, service, or managerial practice that is novel to the organization (whether created or executed by it) and results in a decrease in environmental risks, pollution, and other negative effects associated with resource consumption (including energy use) throughout its entire lifecycle, in comparison to relevant alternatives.' This approach shifts the conventional linear model of production and consumption towards a circular economy, where businesses, economies, and institutions advocate for circular economy frameworks that encourage extensive and fundamental eco-innovation to facilitate the global flow of production inputs (Oduro, 2024). The emergence of the information era has significantly enhanced the role of digitalisation in establishing secure and trustworthy communication infrastructures. It enables efficient and far-reaching communication with minimal effort, facilitating global connectivity. Furthermore, digitalisation acts as a bridge connecting the social, economic, and environmental spheres, contributing to more integrated and sustainable systems (Dabbous et al., 2024). It is also important to highlight the essential role of Artificial Intelligence (AI) in this context, as it further strengthens and optimises these digital connections (Cano-Marin, 2024). It demonstrates proficiency in deciphering complex patterns, assimilating large datasets, and navigating decision-making processes with agility. In the context of striving to achieve net-zero emissions by 2050 (Jesic et al., 2021) underscore the significance of modeling efficient investment systems in eco-innovation. They emphasise the need to implement effective technological and policy frameworks that are essential for mitigating the impacts of climate change, while also addressing barriers such as technological limitations and economic challenges. Bahn-Walkowiak et al. (2021) further investigate the relationship between eco-innovation and digitalisation through case studies from EU member states. Their findings suggest that integrating digital technologies can significantly enhance eco-innovation outcomes, thereby contributing to the objectives of the EU Green Deal and the circular economy. Koval et al. (2022) analyse eco-innovation models within the framework of national decarbonization strategies, emphasising the need for coordinated policies that promote eco-innovation as a critical component in reducing carbon emissions across various sectors. Terzić (2024) posits that eco-innovation is crucial for sustainable growth in EU countries, outlining strategies that can be employed to enhance eco-innovation across various industries. Durán-Romero et al. (2020) propose a Quintuple Helix model that aims to bridge circular economy initiatives with climate change mitigation policies through eco-innovations, emphasising collaboration among diverse stakeholders, including government, industry, academia, and civil society. The results from Şipoş and Ionescu's research provide valuable insights into the dynamics of eco-innovation and its role in fostering sustainable development (Şipoş & Ionescu, 2024). Finally, Domaracká et al. (2023) evaluate eco-innovation practices across EU countries, noting both progress made and significant gaps that require targeted policy interventions. The literature on eco-innovation illustrates its multifaceted role in addressing climate change and fostering sustainable economic practices. The results derived from the fuzzy TISM analysis indicate that "lack of enthusiasm in top management regarding sustainable practices" emerges as the most

influential factor, exerting an impact on all other variables and potentially undermining the long-term viability of SMEs in unstable market conditions. Consequently, industry leaders must address this issue as a strategic priority, as doing so may help mitigate related challenges, strengthen their competitive positioning, and support sustainable development (Karmaker et al., 2023).

The integration of digital technologies, robust policy frameworks, and collaborative approaches is essential for enhancing eco-innovation outcomes throughout Europe. As nations pursue ambitious climate targets, ongoing research will be crucial in identifying effective strategies to overcome existing challenges and capitalise on opportunities for sustainable growth.

Performance indicators in ecological innovation can be categorised into four main areas: product, process, organisational, and marketing. In terms of product, this includes the use of recycled materials, cleaner inputs, reduced raw material consumption, and the design of durable products with fewer harmful components. For processes, key aspects involve minimising waste, reusing components, recycling resources, and supporting renewable energy technologies while engaging in research and development. Organizationally, this involves implementing green HR practices, establishing environmental objectives, conducting audits, and collaborating with stakeholders. Finally, marketing encompasses designing eco-friendly packaging and obtaining quality certifications (Hajdukiewicz & Pera, 2023).

In 2015, European countries excelled in eco-innovation, with significant variations among EU Member States. The European Eco-Innovation Scoreboard categorises countries into leaders, average performers, and those catching up. In 2016, Germany, Luxembourg, and Finland led the rankings, while Greece showed significant improvement, and Belgium experienced a decline (Eco-innovation scoreboard, 2024). Eco-innovation addresses environmental challenges and resource constraints by introducing new technologies, products, and solutions that reduce energy and resource consumption while promoting sustainable economic activity (Bossle et al., 2016). The EU's Eco-Innovation Observatory (EIO, 2025) defines eco-innovation as the introduction of significantly improved products, processes, organizational changes, or marketing solutions that reduce natural resource use and harmful emissions throughout the life cycle. It encompasses not only the creation of new products and services but also the reduction of environmental impacts throughout their design, production, use, reuse, and recycling (Andabaka et al., 2019). Eco-innovation drives resource-efficient growth and facilitates the transition to a circular economy. Maintaining a clean and healthy environment is essential for promoting well-being and quality of life. By promoting approaches that minimise material and energy flows, eco-innovation helps create competitive business models that respect environmental limits (Worakittikul et al., 2025). Attempts are also made to measure eco-innovation and help assess progress in various categories of innovation; assess which nations lead; how much progress nations are making, separating economic growth from environmental degradation, and allow for the analysis of factors influencing this process, eco-innovation and economic and environmental consequences (Arundel & Kemp, 2009). Businesses or non-profit entities can generate eco-innovations, and they may be available in markets or not. Their characteristics can encompass technological, organisational, social, or institutional aspects. The following sections will specifically examine the distinctions among “technological,” “organisational,” “social,” and “institutional” innovations (Rennings, 2000).

Recent studies have increasingly focused on assessing eco-innovation. However, evaluating eco-innovation at the national or regional level presents greater challenges compared to measuring overall innovation performance. This complexity arises from difficulties in defining the audit's scope and establishing appropriate methodologies for quantifying the impacts of implementing environmentally innovative solutions. This area of research remains relatively new in international statistical analysis and is currently being developed by organisations such as the Organisation for Economic Cooperation and Development (OECD) and the European Union (EU). Within the EU, the Eco-Innovation Observatory (EIO) plays a key role in researching eco-innovation, particularly through its efforts to collect data across EU member states. Based on this data, the EIO has developed an Eco-Innovation Scoreboard, which ranks countries according to five indicator groups. Three of these groups focus specifically on eco-innovation: eco-innovation inputs, activities, and outputs, while the remaining two evaluate the outcomes of eco-innovation in terms of resource efficiency and socio-economic benefits (Grassano, 2021; Smol et al., 2017).

While existing studies have explored various aspects of eco-innovation in the EU, there remains a need for deeper insights into how regulations and policies specifically influence the performance of eco-innovation. Additionally, the practices of leading countries in this field warrant further examination to identify transferable strategies that could enhance eco-innovation across the Union.

Research methods

This study investigates the role of eco-innovations in promoting sustainability and mitigating climate change within the European Union. To achieve a comprehensive understanding of this topic, the following multifaceted methodology has been employed.

1. Literature review: An extensive review of existing literature was conducted to establish a theoretical framework and identify key themes and trends in eco-innovation. This included analysis of peer-reviewed journals, policy documents, and reports from relevant organisations such as the European Commission and the Eco-Innovation Observatory.
2. Policy analysis: a detailed examination of EU policies related to eco-innovation was carried out. This involved analysing policy documents, strategic frameworks, and action plans to understand how they support eco-innovation and address sustainability and climate change objectives.
3. Quantitative analysis: statistical data on eco-innovation performance across EU Member States. This analysis focused on identifying patterns, measuring performance indicators, and comparing the effectiveness of various eco-innovation strategies.
4. Eco-Innovation Index analysis: the main approach focuses on assessing the Eco-Innovation Index, which acts as a reference point for evaluating the eco-innovation performance of various nations.
5. In-depth analysis of eco-innovation best practices in countries according to specific categories, depending on the level of development. This analysis involved identifying effective solutions and strategies implemented in both advanced eco-innovation countries and those at earlier stages of development. As a result, it was possible to develop tailored recommendations that align with the specific characteristics and needs of economies at different levels of advancement. This approach contributes to the more effective implementation of eco-innovations on a global scale.

By integrating these methodologies, the research provides a comprehensive overview of how eco-innovation contributes to sustainability and climate change mitigation in the EU. The findings offer valuable insights for policymakers, practitioners, and researchers in advancing eco-innovation strategies and achieving environmental goals.

The subsequent research questions have been formulated to be in line with the aim of the study:

1. What policies and regulations of the European Union support the development and implementation of eco-innovations?
2. Which countries are leaders in eco-innovation?
3. How does the involvement of stakeholders, such as industry, local communities, and non-governmental organisations, impact the success of eco-innovations in the EU?
4. What examples of best practices in eco-innovation could serve as good practices for other EU Member States?
5. Which SDGs are most commonly addressed through eco-innovation solutions?

Evaluating eco-innovation performance in the EU – Results of the research

Eco-innovation plays a crucial role in achieving the goals of the European Green Deal, which aims to transition towards a carbon-neutral and sustainable economy. The Eco-Innovation Index serves as a vital metric for assessing the performance of eco-innovation across European Union member states, reflecting the increasing importance of sustainable practices in contemporary economies.

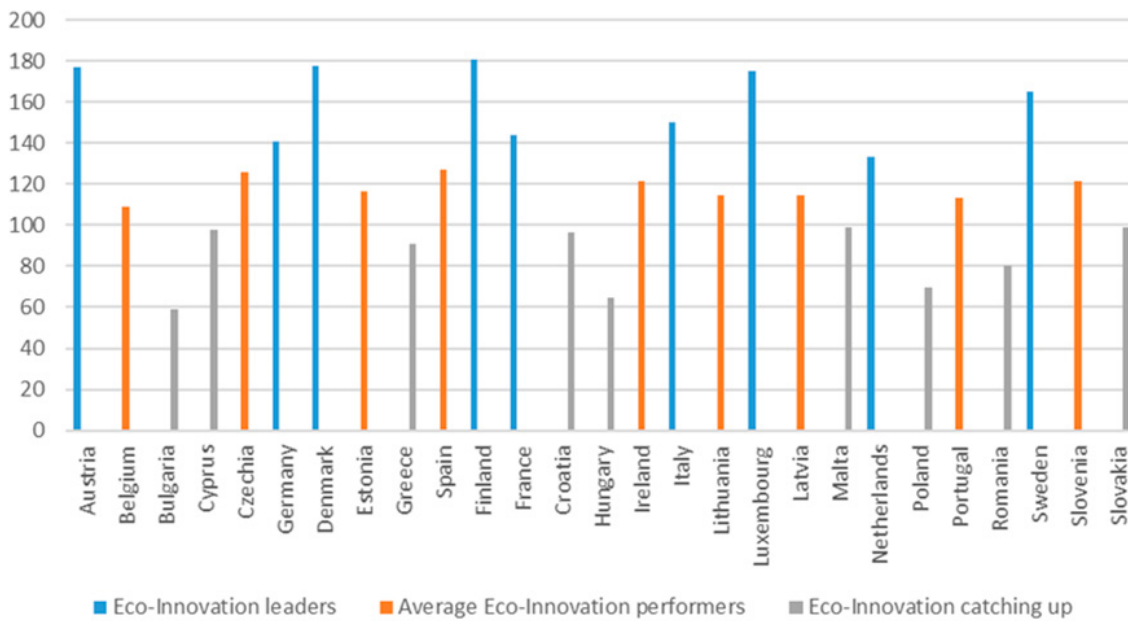


Figure 1. Eco-innovation Index in 2024 in Europe

Source: https://green-business.ec.europa.eu/eeco-innovation_en

According to the Eco-Innovation Index presented in Figure 1, the leading countries are Finland, Luxembourg, Denmark, Austria, and Sweden. The Eco-Innovation Index, which assesses the effectiveness of environmental innovations within EU member states, is structured around five key dimensions:

- Inputs for eco-innovation include investments in financial and human resources directed towards eco-innovative initiatives.
- Activities in eco-innovation: this dimension reflects the level of corporate participation in eco-innovation efforts.
- Outputs of eco-innovation: this refers to the number of patents and scholarly articles associated with eco-innovative practices.
- Outcomes related to resource efficiency: this dimension evaluates how effectively resources are utilised and the intensity of greenhouse gas emissions.
- Socio-economic impacts: this encompasses the beneficial social and economic effects that arise from eco-innovation activities.

The figures below (Figures 2-4) present a comparative analysis of eco-innovation outputs across various European countries, categorising them into three distinct groups: Eco-Innovation Leaders, Average Eco-Innovation performers, and Eco-Innovation Catching-up group. This classification provides insights into the relative performance and progress of different nations in terms of their eco-innovation initiatives and outcomes. Analysing the range of indicators presented, the authors clearly emphasise that Germany and France are leading countries in implementing government environmental policies, whereas Poland ranks at the lower end in terms of implementing governmental environmental protection programs.

Analysing the eco-innovation indicators related to research and development projects, Denmark, Finland, and Belgium emerge as the frontrunners, serving as a crucial driver for advancing sustainable technologies and practices across various industries. The data suggests that these nations prioritise eco-innovation in their R&D agendas, recognising its potential to foster environmental protection, resource efficiency, and the development of innovative green solutions.

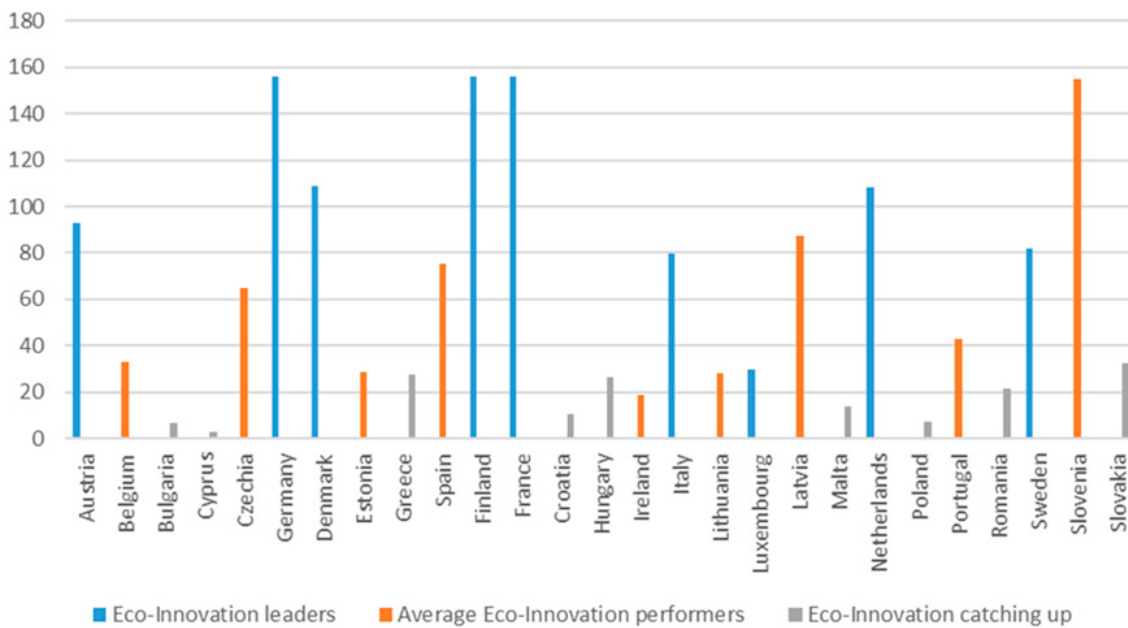


Figure 2. The government's environmental policies
 Source: https://green-business.ec.europa.eu/eco-innovation_en

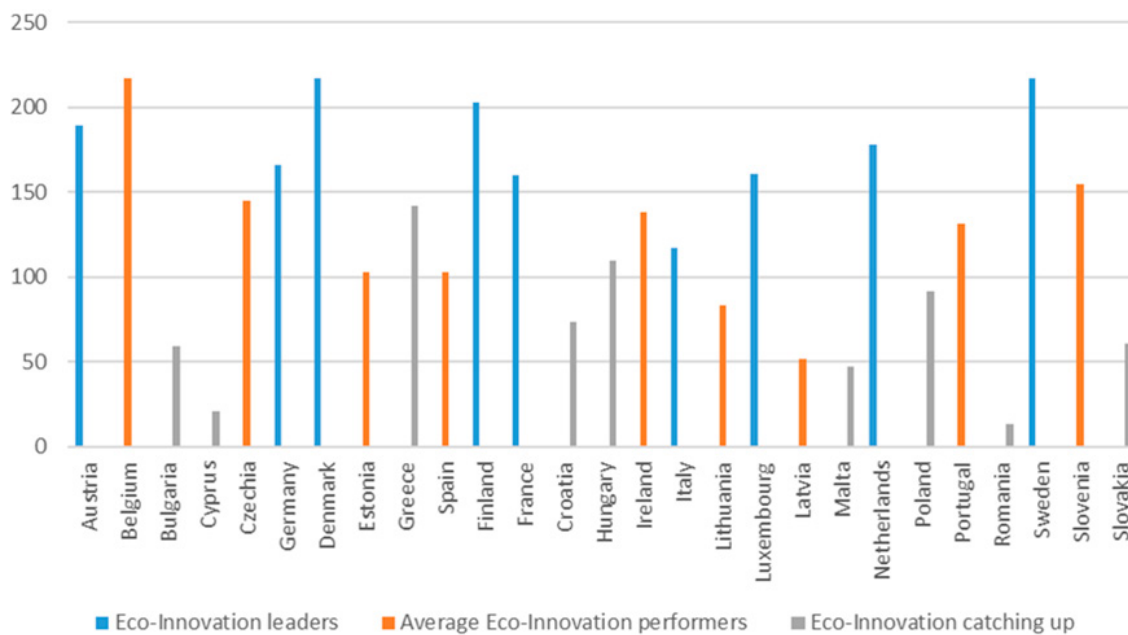


Figure 3. The performance of R&D eco-innovation projects
 Source: https://green-business.ec.europa.eu/eco-innovation_en

Another crucial indicator – employment in the environmental sector – highlights significant activity in countries such as Estonia, Luxembourg, and Finland. These nations have experienced robust growth in green jobs, driven by policy frameworks that support the development of renewable energy, waste management, and energy efficiency initiatives. The transition towards circular economies and the decarbonization of industries has further bolstered job creation in the environmental sector (Figure 5).

An interesting and important indicator in this matter is eco-innovation activity, with Estonia, the Czech Republic, and Slovakia leading the way. These countries are actively developing their eco-innovation infrastructures, showcasing a range of initiatives that demonstrate their commitment to integrating green technologies across various sectors.

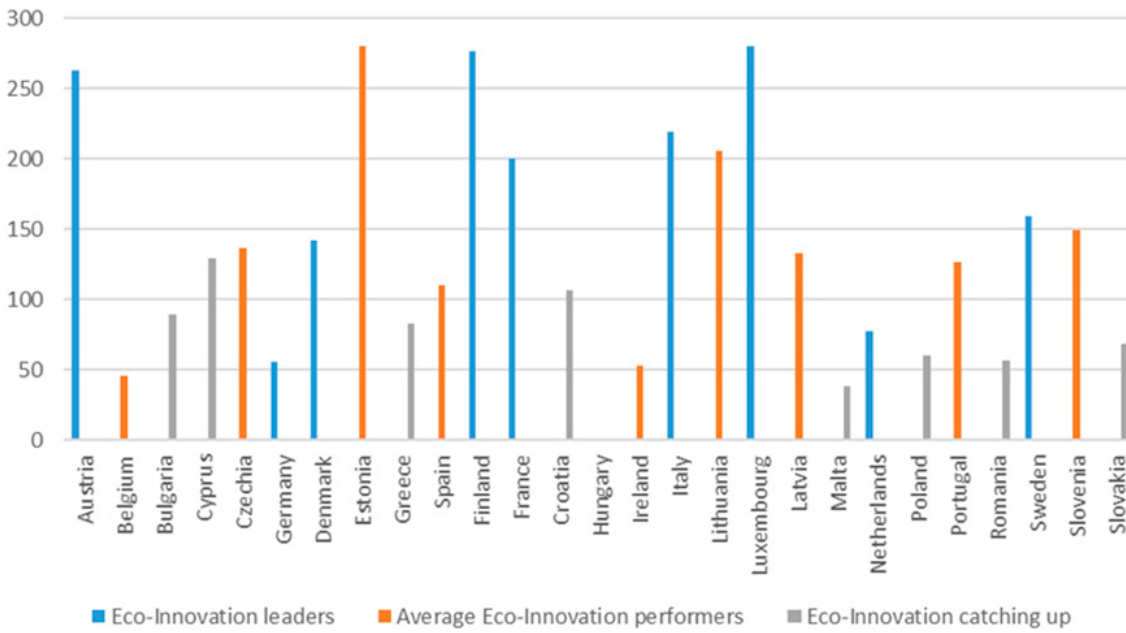


Figure 4. Employment in the environmental sector

Source: https://green-business.ec.europa.eu/eco-innovation_en

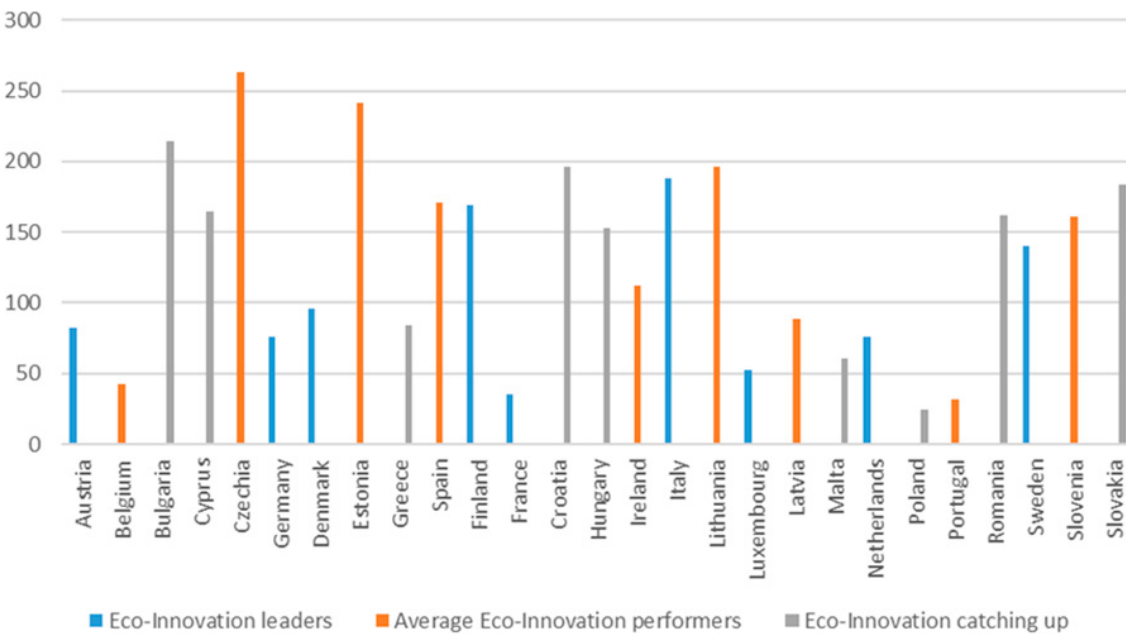


Figure 5. Eco-innovation activity

Source: https://green-business.ec.europa.eu/eco-innovation_en

The key insights from the data highlight varying levels of eco-innovation progress among different countries:

- Eco-innovation Leaders: countries such as Denmark, Finland, and Sweden demonstrate exceptionally high eco-innovation output scores. This suggests these nations have implemented highly effective policies and practices to foster environmental innovation.
- Average Eco-Innovation performers include countries such as Spain, Lithuania, and Estonia, which exhibit moderate performance. This group represents nations that have made significant progress but still have room for improvement to reach the level of the leaders.

- **Eco-Innovation Catching-up group:** countries such as Bulgaria, Croatia, and Cyprus exhibit lower scores. This indicates these nations are in earlier stages of developing their eco-innovation capabilities and infrastructure.

The European Union average appears to fall within the “Average Eco-Innovation performers” category, suggesting a balanced distribution of eco-innovation capabilities across member states. However, this average masks significant disparities between member countries (Mohamedaly et al., 2022). Although almost all nations in the catching-up eco-innovator group have made progress in terms of overall eco-innovation consumption, they have failed to close the access gap between themselves and the leading countries. Their relative performance classification has remained essentially unchanged over the past decade, indicating persistent challenges in eco-innovation development and implementation (Hajdukiewicz & Pera, 2023).

Eco-innovations – Examples and good practices in European countries

Europe boasts numerous examples of eco-innovation initiatives, with best practices spanning various sectors, including renewable energy, water and waste management, sustainable transportation, and agriculture. Many developed nations have established innovation policies to support green innovation (Kemp, 2011). The concept of “eco-innovation” is particularly significant for policymakers and industry leaders who aim to balance environmental protection with economic growth. Many developed nations have established innovation policies to support green innovation, and the concept of “eco-innovation” is particularly significant for policymakers and industry leaders who aim to balance environmental protection with economic growth.

In this context, Sweden and Denmark stand out as leaders in eco-innovation. Both countries have earned an international reputation through decades of consistent commitment to sustainable development and the implementation of forward-thinking policies that prioritise eco-innovation. Their long-standing practices, supported by robust regulatory frameworks and public-private partnerships, have positioned them as global leaders in the field. Sweden stands out in this context, having earned an international reputation for its leadership in environmental issues and for implementing policies that foster eco-innovation in key industries. It has made remarkable progress in renewable energy, particularly in wind power and bioenergy, aiming for 100% renewable electricity production by 2040. The Markbygden Wind Farm exemplifies this commitment, being one of Europe’s largest onshore wind farms. In waste management, Sweden utilises advanced waste-to-energy (WtE) technology, converting waste into energy and even importing waste to fuel its WtE plants, which generate both heat and electricity. The country is also a leader in sustainable transportation, with initiatives such as the *ElectriCity* project in Gothenburg, which integrates electric buses and charging stations into public transportation systems, thereby reducing emissions and noise pollution. Furthermore, Sweden promotes sustainable agriculture by encouraging organic farming practices and reducing the use of chemical fertilisers and pesticides through government policies that support eco-friendly techniques such as precision farming.

Denmark, also recognised as an Eco-Innovation Leader, achieves exceptionally high eco-innovation output scores due to its effective policies and practices. Denmark’s commitment to eco-innovation is exemplified by the Danish Eco-Innovation Programme (MUDP), which funds projects aimed at developing and demonstrating environmental technologies. This program supports initiatives that enhance sustainability across various sectors, focusing on areas such as climate adaptation, waste recycling, and cleaner air. Notable projects include the development of measurement units to optimise aeration and reduce nitrous oxide emissions in wastewater treatment plants, as well as efforts to promote sustainable construction practices. Denmark’s strategic investments in green technologies and its robust framework for supporting eco-innovation position it as a global leader in sustainable development.

Spain is categorised as an Average Eco-Innovation performer, indicating moderate progress in eco-innovation capabilities. Notable examples of eco-innovation in Spain include initiatives from the Basque Country, where over 150 industrial companies have adopted circular practices such as life cycle assessment and eco-design. The Basque Ecodesign Centre, established in 2011, has played a pivotal role in integrating life cycle thinking into corporate strategies, resulting in significant

economic and environmental benefits. Additionally, the Circular Economy Innovation Programme has completed numerous demonstration projects aimed at fostering circular business opportunities for small and medium-sized enterprises (SMEs), potentially creating new green jobs and substantially reducing CO₂ emissions. Furthermore, Spain's commitment to renewable energy is evident through its investments in wind and solar power technologies, which contribute to the country's transition toward a more sustainable energy landscape. These efforts collectively underscore Spain's ongoing journey toward enhancing its eco-innovation performance within the framework of a circular economy.

Lithuania, classified as an Average Eco-Innovation performer, demonstrates significant progress in eco-innovation with several noteworthy initiatives. One prominent example is the National Energy and Climate Action Plan, which aims for a 45% share of renewable energy in final energy consumption by 2030, focusing on enhancing energy efficiency and reducing fossil fuel dependency. Another example is the Long-Term Renovation Strategy, which seeks to transform the existing building stock into energy-efficient structures by 2050. This strategy mandates that all new public buildings meet high energy efficiency standards and incorporate sustainable materials, such as requiring that at least 50% of construction materials be wood or organic by 2024. Additionally, DPD Lithuania has introduced a sustainability strategy that focuses on reducing transport pollution by electrifying its vehicle fleet. The company aims to achieve net-zero CO₂ emissions by 2040 and has already integrated electric vehicles into its operations, demonstrating a commitment to sustainable logistics.

Bulgaria, categorised as part of the Eco-Innovation Catching-up group, is making strides in eco-innovation with several notable projects. One significant initiative is the Waste-to-Energy project, which established a wood pellet plant and a combined heat and power (CHP) plant. The project not only reduces carbon emissions by about 3,480 tonnes but also addresses waste management challenges by minimising landfill usage. Another example is the installation of solar panels in public institutions across Bulgaria, particularly in Blagoevgrad, where 18 kindergartens and three social institutions have benefited from this initiative. Additionally, the start-up Nasekomo focuses on sustainable protein production through insect farming, aiming to create an environmentally friendly alternative for animal feed. This innovative approach has the potential to reduce CO₂ emissions and alleviate pressure on fish stocks by providing new protein sources.

Croatia, also classified within the Eco-Innovation Catching-up group, is actively developing its eco-innovation capabilities through various initiatives. One notable example is the Digital Innovation and Green Technology Project (DIGIT), funded by the World Bank, which aims to facilitate the digital transformation of the Croatian economy while promoting environmentally friendly practices. Additionally, Croatia has initiated programs to support renewable energy sources, particularly solar energy. For instance, local governments are implementing solar panel installations on public buildings, which not only reduces carbon emissions but also lowers energy costs for municipalities. Moreover, Croatian startups are emerging in the green technology sector, focusing on sustainable solutions, including waste management and recycling technologies. These innovations aim to improve waste processing efficiency and promote circular economy principles within local communities. The aforementioned examples demonstrate how eco-innovation practices across Europe contribute to sustainability while simultaneously addressing pressing environmental challenges. The integration of sustainable technologies and methodologies at local, national, and regional levels underscores Europe's commitment to fostering a more sustainable future. This multifaceted approach not only enhances environmental resilience but also promotes economic growth and social well-being, highlighting the critical role of innovation in achieving sustainability objectives. Table 1 presents an analysis of eco-innovation across various country groups, illustrating the diverse challenges and success factors associated with eco-innovation practices within the EU. This comparative overview offers insights into how various nations are utilising eco-innovation to address environmental challenges and enhance their economic resilience. By examining successful strategies implemented by countries within various groups, other nations can adopt effective solutions tailored to their specific contexts.

Table 1. Eco-Innovation analysis across country groups and recommendations for other countries

Country group	Country	Key challenges	Success factors	Recommendations for other countries
Eco-innovation leaders	Sweden	<ul style="list-style-type: none"> achieving 100% renewable electricity by 2040 reducing dependence on non-renewable energy managing growing waste streams 	<ul style="list-style-type: none"> strong government policies promoting renewable energy and sustainable practices advanced waste-to-energy (WtE) technologies investments in wind power and bioenergy successful sustainable transport projects precision and organic farming supported by policies 	<ul style="list-style-type: none"> developing clear, long-term eco-innovation goals (e.g., renewable energy targets) integrating advanced waste management systems fostering partnerships between government and private sectors for sustainable transport and agriculture promoting public awareness about eco-friendly practices
	Denmark	<ul style="list-style-type: none"> climate adaptation in urban and rural areas reducing industrial emissions 	<ul style="list-style-type: none"> Danish Eco-Innovation Programme (special-purpose fund for environmental technology) focus on cleaner air, waste recycling, and sustainable construction strategic investments in green technologies development of efficient wastewater treatment technologies to reduce emissions 	<ul style="list-style-type: none"> creating targeted funding programs to support green technologies encouraging public-private partnerships for innovation prioritizing emission reduction in industrial processes sharing expertise on integrating sustainability into national infrastructure and construction
Eco-Innovation average	Spain	<ul style="list-style-type: none"> transitioning industries to circular economy principles achieving energy sustainability goals reducing waste and CO2 emissions 	<ul style="list-style-type: none"> Circular Economy Innovation Programme fostering circular business opportunities investments in wind and solar power encouragement of SMEs to adopt sustainable practices 	<ul style="list-style-type: none"> promoting circular economy practices at regional and national levels supporting SMEs through funding and access to green technology investing in renewable energy establishing regional hubs to share best practices for eco-innovation
	Lithuania	<ul style="list-style-type: none"> reducing reliance on fossil fuels improving building energy efficiency electrifying transport systems 	<ul style="list-style-type: none"> National Energy and Climate Action Plan, aiming for 45% renewable energy by 2030 long-term Renovation Strategy mandating energy-efficient building practices corporate sustainability strategies 	<ul style="list-style-type: none"> setting specific targets for renewable energy usage and energy efficiency encouraging public-private collaboration for sustainable building renovation fostering corporate sustainability initiatives providing incentives for green transport solutions
Eco-Innovation catching-up	Bulgaria	<ul style="list-style-type: none"> limited capacity for renewable energy infrastructure high dependency on landfills for waste management 	<ul style="list-style-type: none"> waste-to-energy projects installation of solar panels in public institutions start-ups like promoting innovative solutions 	<ul style="list-style-type: none"> leveraging start-ups to develop scalable green solutions focusing on small-scale renewable energy projects to gradually increase capacity supporting rural areas with targeted eco-innovation initiatives fostering international cooperation to access eco-innovation expertise
	Croatia	<ul style="list-style-type: none"> developing green technology sector scaling up renewable energy solutions improving waste management efficiency 	<ul style="list-style-type: none"> digital Innovation and Green Technology Project (DIGIT) supported by the World Bank solar panel installation projects on public buildings emerging start-ups in waste management and recycling technologies 	<ul style="list-style-type: none"> investing in digital and green technology integration encouraging start-ups in the eco-innovation sector with funding and mentorship sharing experiences from pilot projects to replicate successful initiatives regionally

Discussion and future research

The EU has positioned itself as a leader in promoting eco-innovation, emphasising coordinated efforts across public, private, and third sectors to facilitate the transition towards a sustainable economy. This focus aligns with the principles of sustainable development and the circular economy, underscoring the critical role of technological advancements in addressing the inherent tension between economic growth and environmental limits (Ekins, 2010). Eco-innovation, defined as innovative processes, products, or services that minimise environmental impacts while fostering economic and social benefits, forms the backbone of the EU's sustainability strategy. Public policies play a crucial role in this regard, establishing frameworks that mitigate market failures and incentivise investments in green technologies (Sarkar, 2013). Since 2017, the European Eco-Innovation Index has reflected significant progress in eco-innovation adoption, driven by increased green investments and expanded employment in R&D sectors. Leading EU countries, including Sweden, Denmark, and Finland, owe their high performance to robust policy frameworks and sustained investment in R&D, whereas nations with weaker regulatory environments lag (Szilagyí et al., 2018). This disparity underscores the crucial interplay between policy support, stakeholder engagement, and investment strategies in promoting eco-innovation. Best practices identified in leading countries can serve as valuable models for other EU member states seeking to enhance their eco-innovation capabilities (Hojnik et al., 2024). The findings align with those of Tomashuk and Baldynyuk (2023), who emphasise the importance of cross-sector collaboration in fostering eco-innovation as a cornerstone of sustainable development. This synergy between policy and innovation not only enhances environmental performance but also fosters economic growth, positioning Europe as a leader in the global shift towards sustainability. Various EU member states have adopted distinct eco-innovation strategies, with countries like Sweden, Denmark, Luxembourg, and Finland emerging as leaders due to their robust research and development initiatives. Despite the overall progress in eco-innovation, significant disparities exist among EU member states, influenced by factors such as governmental support, regulatory frameworks, and stakeholder engagement. Disparities in performance among EU nations can be attributed to differences in regulatory frameworks, levels of public investment, and stakeholder engagement (Janahi et al., 2021). Moreover, eco-innovation directly contributes to achieving Sustainable Development Goals (SDGs), particularly SDG 13 (climate action) and SDG 12 (responsible consumption and production). These objectives are amplified by targeted policies that balance regulatory support with green investment, as early-stage funding for eco-industries is pivotal for long-term success. This aligns with Sarkar (2013), who emphasised the need for eco-industrial development to achieve green growth. The concept of eco-innovation encompasses various dimensions, including the development of new products and processes that aim to reduce environmental impacts through principles rooted in the circular economy. Our findings contribute to the existing literature by providing new empirical evidence on the drivers of eco-innovation adoption, highlighting the interplay between public policies, investments, and stakeholder engagement. Specifically, our study highlights the crucial importance of striking a balance between policy support and green investments, as well as fostering inclusive stakeholder collaboration, to optimise eco-innovation outcomes. This aligns with the broader recognition of eco-innovation as not merely a response to pressing environmental challenges but a strategic imperative for achieving long-term sustainability and resilience in an increasingly complex global landscape (Ullah et al., 2024; Gilli et al., 2024). Future research could delve deeper into the comparative analysis of eco-innovation practices across EU member states, exploring the role of socio-economic factors in shaping adoption rates. Additionally, examining the long-term impacts of eco-innovation on regional development and resilience would provide policymakers and practitioners with valuable insights. While this study identifies numerous challenges within the realm of eco-innovation, it also points to a wealth of viable solutions that merit further exploration to advance both theoretical and practical understanding.

Conclusions

The European Union faces urgent environmental challenges, including climate change, resource depletion, and waste management. To address these issues, eco-innovation – the development and application of new products, services, and processes that reduce environmental impact – has emerged as a crucial strategy. Policymakers, industries, and civil society must work together to drive this transition toward a more sustainable, circular economy. This approach not only addresses pressing ecological challenges but also aligns with the European Union's (EU) commitment to achieving climate neutrality by 2050. The integration of eco-innovation into policies and practices is essential for fostering cleaner and more competitive industries, reflecting a broader trend towards sustainable economic growth (Janahi et al., 2021).

A key takeaway from this publication is the necessity for continued collaboration among industry stakeholders, society, government entities, and businesses in implementing the eco-innovations discussed herein. Future efforts should prioritise the development of eco-innovation policies that create strategic frameworks to promote sustainable practices and technologies. Additionally, the adoption of green technologies is crucial for countries seeking to improve their eco-innovation performance, highlighting the pivotal role technology plays in achieving environmental objectives. Furthermore, sustainable business models must be emphasised, as they aim to generate economic value while minimising ecological impacts, necessitating a commitment to sustainable innovation for improved eco-performance. Public-private partnerships (PPPs) should also be leveraged to harness resources and expertise for driving sustainable projects, thereby identifying effective strategies for enhancing eco-innovation. Lastly, embracing circular economy practices is crucial for reducing waste and promoting resource reuse, which is fundamental to transitioning toward more sustainable economic frameworks. The full engagement of European economic instruments, along with the initiation of additional projects in this domain, will facilitate the achievement of environmental goals aimed at improving ecological components, aligning closely with the European Union's environmental protection policies and objectives.

The transition to a more sustainable, eco-innovative economy is a crucial objective for European countries as they strive to meet their climate goals and address environmental challenges. In this context, analysing the eco-innovation performance of various nations provides valuable insights into the challenges, successes, and strategies that shape their paths toward sustainability. By examining countries, we can better understand the factors influencing their eco-innovation progress and identify key recommendations for accelerating change across Europe. As Terzić mentioned, "Governments that are currently putting green measures into place may find that the performance of the analysed economies can also provide helpful guidance for achieving sustainable development. With the right measure of Eco-Innovation, the economies of the EU can also evaluate the overall welfare of the nations (Terzić, 2024).

The challenges associated with implementing eco-innovation vary significantly across countries depending on their level of economic development, policy frameworks, and technological capabilities. By analysing countries from different geographical regions and performance groups – Leaders, Average Performers, and the Catching-Up Group – it is possible to identify the unique barriers each group faces in advancing their eco-innovation agendas. These barriers could include regulatory hurdles, access to finance, and organisational and market challenges (Castagneto Gisse et al., 2018). Leaders like Sweden and Denmark are tasked with overcoming technical and financial barriers to achieve ambitious sustainability targets such as climate neutrality and advanced waste and emission management, reflecting their high eco-innovation performance and commitment to sustainability. Average Performers such as Spain and Lithuania grapple with transitioning industries and adopting circular economy principles on a broader scale. Meanwhile, Catching-Up countries such as Bulgaria and Croatia must address foundational issues, including limited infrastructure and institutional support, to unlock their eco-innovation potential. Addressing these challenges requires tailored strategies that reflect each country's unique context. Collaborative frameworks, increased investment in green technologies, and knowledge-sharing platforms will be essential for fostering innovation and overcoming these barriers. By acknowledging and addressing these key challenges, European nations can collectively advance toward a more sustainable and innovative future. The Corporate Venture

Capital (CVC) ecosystem plays a crucial role in the broader entrepreneurial environment. Its symbiotic cultivation mechanism contributes to the stability of interdependent relationships by enabling system actors to adapt, realign, and cluster in ways that support the co-creation and distribution of value. This dynamic fosters equilibrium and sustainable growth within the ecosystem while continually enhancing the overall value of the innovation landscape (Meng et al., 2023).

This article contributes to the theoretical understanding of how eco-innovation performance can serve as a framework for evaluating national sustainability efforts, particularly in the context of the European Union. Practically, it offers a typology of country-specific challenges and policy recommendations tailored to performance clusters, providing actionable insights for policymakers and stakeholders.

Key recommendations for advancing eco-innovation in Europe can be categorised into several critical areas, each addressing specific challenges faced by countries across different performance groups. Above all, however, these recommendations highlight the importance of tailored strategies and collaborative efforts in advancing eco-innovation across Europe. The following sections outline actionable recommendations and their potential impact on fostering eco-innovation across the EU:

- Policy development – clear and strategic policy frameworks are essential for fostering eco-innovation. Governments should establish long-term renewable energy targets and provide incentives for businesses to adopt green practices. Such policies can create an enabling environment that encourages sustainable investments and technological advancements while ensuring alignment with national and EU-wide climate goals.
- Technology investment – countries should prioritise funding for advanced technologies such as waste-to-energy systems, renewable energy solutions, and green logistics. These investments not only support economic growth but also drive significant environmental benefits by reducing emissions, optimising resource use, and enhancing energy efficiency. Targeted funding for research and development (R&D) in eco-innovative technologies can accelerate their deployment and ensure their accessibility to both public and private sectors.
- Knowledge sharing is particularly important for countries in the Catching-Up and Average performance groups. Establishing knowledge-sharing platforms led by eco-innovation leaders like Sweden and Denmark can provide valuable insights and best practices. For example, expertise in waste management and sustainable construction can help less advanced countries develop effective strategies and solutions tailored to their unique contexts. Collaborative initiatives, such as EU-funded programs and cross-border partnerships, can facilitate the transfer of knowledge and foster a culture of innovation across member states.
- Circular economy practices – these practices must be promoted across all performance groups. By embracing circular economy principles, countries can enhance resource efficiency, minimise waste, and create opportunities for sustainable economic growth. This approach encourages the reuse and recycling of materials, reducing environmental impact and fostering resilience in supply chains. Policymakers and businesses should work together to integrate circular economy models into national strategies, ensuring that eco-innovation aligns with broader sustainability objectives.

The research highlights the necessity of implementing sustainable policies to support long-term growth and development. It is expected that the formulation and adoption of well-designed, environmentally conscious policies will improve ecological conditions and sustain the progress of each member state of the European Union. By focusing on policy frameworks, technological advancements, collaborative knowledge exchange, and adopting the principles of the circular economy, eco-innovation outcomes in the EU can be improved significantly. (Teshome, 2024). Adopting these strategies to the specific needs of countries at different stages of development will help move to sustainability more equitably and efficiently. Such initiatives will not only assist in achieving climate and environmental targets but also strengthen the EU's position as a leading pioneer in eco-innovation and sustainability.

Further research should explore the long-term effectiveness of eco-innovation policies at the sectoral level, particularly in high-impact areas such as energy, transport, agriculture, and manufacturing. Additionally, the role of digitalisation – through technologies such as big data, artificial intelligence, and smart infrastructure – should be investigated as a catalyst for scaling eco-innovation and

improving its monitoring and evaluation. Importantly, future studies should also examine how to actively engage citizens and small and medium-sized enterprises (SMEs) in sustainable transitions, as their participation is critical to ensuring wide-scale behavioural change and inclusive green growth.

These proposed directions contribute both to the theoretical refinement of eco-innovation frameworks – by incorporating sectoral and digital dimensions – and to practical policymaking by offering targeted, evidence-based recommendations for more effective and inclusive implementation. These directions would not only refine the theoretical frameworks surrounding eco-innovation but also support more adaptive, data-driven, and participatory policymaking across the EU.

The contribution of the authors

Conceptualisation, N.D., D.M., Ł.Sz.; literature review, N.D., D.M., Ł.Sz.; methodology: N.D., D.M., Ł.Sz.; formal analysis: Ł. Sz.; writing, N.D., D.M.; conclusions and discussion: N.D., D.M., Ł.Sz.

The authors have read and agreed to the published version of the manuscript.

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EKO-INNOWACJE W KRAJACH UNII EUROPEJSKIEJ – DOŚWIADCZENIA I DOBRE PRAKTYKI

STRESZCZENIE: Rozwój i wdrażanie ekoinnowacji stanowi istotny element w przeciwdziałaniu zmianom klimatycznym i we wspieraniu zrównoważonego rozwoju w Europie. Niniejszy artykuł analizuje integrację ekoinnowacji w ramach polityki Unii Europejskiej, podkreślając ich znaczenie w realizacji celów zrównoważonego rozwoju. W ramach zastosowanej metodologii badawczej wyróżniono trendy w zakresie ekoinnowacji, a analizę wzbogacono o studia przypadków udanych praktyk w wybranych państwach członkowskich UE. Wyniki wskazują na istotne różnice w poziomie wdrażania ekoinnowacji, identyfikując zarówno kraje przodujące, jak i te opóźnione w ich adopcji. Dyskusja koncentruje się na implikacjach tych wyników dla przyszłych badań i kształtowania polityk, podkreślając pilną potrzebę integracji ekoinnowacji w krajowych i regionalnych strategiach transformacji klimatycznej. Taka integracja jest kluczowa nie tylko dla osiągnięcia neutralności klimatycznej do 2050 roku, ale także dla utrzymania pozycji Europy jako lidera w dziedzinie czystych technologii w obliczu wyzwań gospodarczych i geopolitycznych. Badanie podkreśla podwójną rolę wsparcia politycznego oraz inkluzywnej współpracy między interesariuszami, wskazując ekoinnowacje jako strategiczny priorytet w dążeniu do zrównoważonego rozwoju i wzmocnienia globalnej odporności.

SŁOWA KLUCZOWE: polityka środowiskowa, ekoinnowacje, rozwój zrównoważony, Unia Europejska